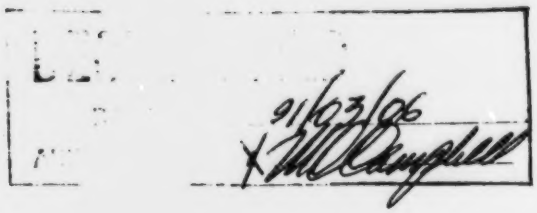

A LABORATORY EVALUATION OF SILICA SAND FROM GOLDEN, BRITISH COLUMBIA

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A LABORATORY EVALUATION OF SILICA SAND FROM GOLDEN, BRITISH COLUMBIA

by

P.R.A. Andrews*

SUMMARY

A combination of flotation, magnetic separation and acid leaching resulted in a product which analyzed 68 ppm Fe_2O_3 and 444 ppm Al_2O_3 on -630 µm +100 µm silica sand. Grinding to 100% passing 53 µm followed by acid leaching further reduced the Fe_2O_3 level to 56 ppm.

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INTRODUCTION

Mountain Minerals Co. Ltd., Lethbridge, Alberta has an extensive high grade deposit of sandstone and quartzite near Golden, British Columbia. The majority of the deposit is composed of a hard, dense quartzite, while the remainder is comprised of a friable sandstone.

While processing and washing produce a silica sand which meets 'flint' grade glass sand specifications, the company is interested in establishing processes by which it can reduce the total impurities to ≈15 ppm and, in particular, Fe_2O_3 to between 3 and 5 ppm. If the Fe_2O_3 content could be reduced to this level then the company would be able to supply silica sand to more attractive markets, e.g., fibre optic fibres, photovoltaic, and specialty radiation shielding glass.

Assistance in solving this problem was requested under the START program and Job No. 025196 was allocated to this project.

SCOPE OF STUDY

The degree to which the Fe_2O_3 level can be significantly reduced will depend on whether the impurities, in particular Fe_2O_3, occur as coatings on quartz grains, as discrete liberated grains, as inclusions in quartz or some combination of these. A mineralogical study to determine in what form the iron oxide minerals occur and the identification of other impurities would therefore constitute an important part of the study.

Following the mineralogical study, a brief beneficiation study, including flotation and magnetic separation, will be conducted, with the object of reducing iron oxide and alumino-silicate mineral impurities. Samples of the products from the various beneficiation methods will then be submitted for leaching evaluation and the leached products sent, by agreement, to Ontario Research Foundation, Mississauga, Ontario for detailed chemical analysis.

SAMPLE PREPARATION

Two separate 30 kg samples were received, a pre-washed -630 µm +100 µm silica sand and an unprocessed lump sandstone. Since the washed sand sample had already been processed, it was decided to conduct testwork on this

sample, and if the desired goal was reached, to then repeat the testwork on the lump material.

Approximately 10 kg was riffled from the processed sand, which was further riffled into 1 kg lots for further processing. A head sample was reserved for size analysis, chemical analysis and mineralogical examination. After completion of the size analysis the various size fractions were examined under the binocular microscope to determine shape characteristics. The results are presented in Table 1.

MINERALOGY

A representative head sample was examined mineralogically to identify contaminating minerals and type of middlings. The minerals present in the head sample are quartz and trace amounts of calcite, dolomite, ankerite, clay minerals (probably kaolinite), zircon, iron-poor and iron-rich alumino-silicates (probably pyroxene), sericite, biotite, hematite, goethite and pyrite.

The zircon and most of the calcite and alumino-silicates in the fractions are present as free grains. Some of the calcite and alumino-silicates, however, are intergrown with dolomite and ankerite. The latter two minerals occur only as intergrowths. The quartz is present as free grains but some contain small inclusions of calcite, mica, dolomite, clay minerals, hematite and pyrite. The hematite and pyrite are generally present as very small grains, and most are completely enclosed in the quartz.

The iron is present as:

- minute inclusions of hematite and rarely pyrite in quartz and calcite;
- as separate goethite grains;
- as separate iron-alumino-silicate grains;
- as ankerite;
- possibly as a film of iron oxide on quartz.

The ankerite is present as intergrowths with dolomite, calcite and quartz. The presence of an iron oxide film is interpreted on the basis of detecting iron at a few points on the edges of the grains. The proportion of iron occurring in each mode was not determined.

It should be possible to remove liberated iron-bearing minerals and some of the hematite inclusions in quartz by high intensity magnetic separation. Additional iron in the form of ankerite and the film of iron oxide should be removed by acid leaching.

PROCESSING

FLOTATION

The procedure employed for the removal of impurities was based on previous experience with similar material. Iron oxide minerals are first floated using Aerofloat 840[(1)], a petroleum sulphonate collection, followed by cationic flotation of alumino-silicate minerals using Duomeen TDO[(2)], n-tallow -1,3 -diamino propane dioleate.

The following general procedure was therefore adopted using 1 kg portions of feed material.

Stage 1 Iron oxide flotation using Aerofloat 840 at pH 3.5-4.0, employing high pulp density (≈50% solids) conditioning.

Stage 2 Alumino-silicate flotation using Duomeen TDO at pH 2.0-2.2, employing high pulp density (≈50% solids) conditioning.

In each stage, high pulp density conditioning was conducted for 5 min with Dowfroth 250 being added as frother. Immediately following conditioning the pulp density in each stage was reduced to 30% solids and flotation conducted until completion which was generally 5 min. At the end of stage 1 the quartz concentrate was filtered and washed twice to remove any residual petroleum sulphonate before repulping and proceeding to stage 2.

At the completion of stage 2 all products were filtered, dried and prepared for chemical analysis. The results of the best flotation test are presented in Table 2.

MAGNETIC SEPARATION

High intensity magnetic separation was conducted on ≈100 g of the original head sample and ≈100 g of the quartz flotation concentrate, using the Sala HGMS (high gradient magnetic separator) to compare iron oxide removal by flotation and magnetic separation. The results of the magnetic separation tests are presented in Table 3.

ACID LEACHING

A leaching study was conducted on three products; the pre-washed head, the non-magnetic fraction from the head, and the non-magnetic fraction from the quartz flotation concentrate.

Each sample was first washed in distilled water to remove any extraneous matter, and then treated with hot 0.5 M NaOH solution for 24 hours to remove any soluble acidic impurities. After washing in distilled water the resultant samples were extracted with hot HCl with 50% dilution for 24 hours. The resultant leached products were again washed in distilled water, dried and prepared for chemical analysis.

CHEMICAL ANALYSIS

Since the level of accuracy required was to within 5 ppm, samples chosen for chemical analysis were ground to -75 µm in a laboratory agate grinder, so that there would be no contamination from either Fe_2O_3 or Al_2O_3. the samples were then sent to the Ontario Research Foundation for detailed chemical analysis.

Each sample was first dried at 120°C and then ignited at 750°C for 3 hours in a platinum crucible to determine the loss of ignition (LOI).

Silica was determined by weight loss after exhaustive hydrofluoric-sulphuric acid treatment. The total solids were dissolved with concentrated hydrofluoric and hydrochloric acids. The solutions were diluted to volume for analysis by direct current plasma emission spectrophotometry.

Apart from SiO_2, Al_2O_3 and Fe_2O_3, each sample was analyzed for several other oxides. The results of chemical analyses are reported in Table 4.

DISCUSSION OF RESULTS

A combination of flotation of iron oxide and alumino-silicate minerals followed by magnetic separation of any remaining iron oxide minerals in the quartz flotation concentrate, resulted in a product which analyzed 108 ppm Fe_2O_3 and 519 ppm Al_2O_3. Subsequent treatment by acid leaching reduced these impurity levels to 68 ppm Fe_2O_3 and 444 ppm Al_2O_3.

These levels were the lowest that could be achieved on -630 µm +100 µm material; further reduction of Fe_2O_3 only being possible by grinding

followed by additional treatment. In this respect, a 50 g sample of quartz flotation concentrate was ground to 100% passing 53 µm (300 mesh) and acid leached. The reduction of Fe_2O_3, however, was only to 56 ppm. This level compares with the 51 ppm Fe_2O_3 level reportedly obtained by Consumers Glass.

CONCLUSIONS

Based on this testwork it appears that the levels of Fe_2O_3 and Al_2O_3, even after acid leaching of ground minus 53 µm material, are still too high for the silica sand to be suitable for the manufacture of fibre optic fibres, photovoltaic and specialty radiation shielding glass.

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Table 1 - Size analysis and mineral shape characteristics of the head

Size (μm)	Wt %	Description
-630+400	8.9	Rounded to sub-rounded grains with minor iron staining; a few opaque grains present
-400+315	16.9	Rounded to sub-rounded grains; minor iron staining; some angular grains and some opaques
-315+200	34.2	Rounded to sub-rounded grains; minor iron staining; angular grains increased slightly; some opaques
-200+160	13.5	Sub-rounded to angular grains; minor iron staining; minor opaques
-160+100	22.4	Mainly angular grains with a few sub-rounded grains; minor iron staining; minor opaques
-100+ 70	3.1	Mainly angular grains but still some sub-rounded grains; minor iron staining; minor opaques, though slightly more than in previous size fraction
-70	1.0	Mainly angular grains; minor iron staining; minor opaques, similar in amount to previous size fraction

Table 2 - Flotation of iron oxide and alumino-silicate minerals

Products	Wt	Analysis %			Distribution %		
	%	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3
Iron oxide float	0.4	49.50	1.26	1.89	0.2	8.9	29.4
Alumino-silicate float	3.2	98.67	0.19	0.15	3.2	9.8	17.1
Quartz concentrate	96.4	99.72	0.0528	0.0157	96.6	81.3	53.5
Calculated head	100.0	99.47	0.0625	0.0283	100.0	100.0	100.0
Measured head	--	99.53	0.0752	0.0219	--	--	--
Leached head	100.0*	--	--	0.0073	--	--	25.8

*Assuming negligible weight loss after leaching

Flotation reagent data:	Collector	g/t
Iron oxide float	Aerofloat 840	252
Alumino-silicate float	Duomeen TDO	177

Table 3 - Magnetic separation of iron oxide minerals from head material and quartz flotation concentrate

A. Head material

Products	Wt	Analysis %		Distribution %	
	%	Fe_2O_3	Al_2O_3	Fe_2O_3	Al_2O_3
Magnetics	5.0	0.27	0.15	56.3	12.1
Non-magnetics	95.0	0.0111	0.0577	43.7	87.9
Calculated head	100.0	0.0241	0.0623	100.0	100.0
Measured head	--	0.0219	0.0752	--	--
Leached head	95.0*	0.0065	0.0470	25.9	71.6

B. Quartz flotation concentrate

Products	Wt	Analysis %		Distribution %	
	%	Fe_2O_3	Al_2O_3	Fe_2O_3	Al_2O_3
Magnetics	3.6	0.09	0.07	13.1	4.1
Non-magnetics	92.7	0.0108	0.0519	40.4	77.2
Calculated head	96.3	0.0138	0.0526	53.5	81.3
Measured head	--	0.0157	0.0528	--	--
Leached head	92.7*	0.0068	0.0444	25.4	66.1

*Assuming negligible weight loss after leaching.

Table 4 - Chemical analyses of selected products

Constituent		Sample No.						
		1	2	3	4	5	6	7
Moisture	- %	0.015	0.018	0.020	0.019	0.016	0.017	0.022
L.O.I. 750°C	- %	0.18	0.070	0.13	0.075	0.063	0.071	0.10
SiO_2	- %	99.53	99.72	99.63	99.73	99.79	99.78	99.81
CaO	ppm	984	102	770	129	83	41	50
Al_2O_3	"	752	528	577	519	293	470	444
Fe_2O_3	"	219	157	111	108	73	65	68
MgO	"	261	134	295	125	129	74	78
K_2O	"	166	125	134	127	58	11	98
Na_2O	"	50	44	51	47	38	32	74
TiO_2	"	98	85	86	84	82	91	75
P_2O_5	"	26	14	23	17	9	12	11
CuO	"	24	15	17	11	17	23	20
MnO	"	3.4	2	3	2	1	1	1
ZnO	"	13	15	8	7	11	12	9
ZrO_2	"	3	2.3	3.5	2	3	2	2
V_2O_5	"	<0.04	<0.04	0.4	<0.04	<0.04	<0.04	<0.04
NiO	"	0.9	5	3.3	4	0.1	4	4.5
CrO_3	"	15	15	11	13	12	13	15
TOTAL		99.99	99.93	99.99	99.94	99.95	99.96	100.03

Sample Identification

No.1 Head
2 Flotation Concentrate
3 Non-magnetics from Head
4 Non-magnetics from Flotation Concentrate
5 Leached Head
6 Leached Non-magnetics from Head
7 Leached Non-magnetics from Flotation Concentrate